LAYING THE FOUNDATION
Building Academic Excellence

Barbie® Doll Bungee Jumping
Graphing and Extrapolating Data

About this Lesson

Through this activity, students will gain an appreciation for simulations and the beauty of mathematics in science by determining the relationship between the number of rubber bands and the jump height that will allow a safe bungee jump for Barbie®.

This lesson is included in the LTF Module 1.

Objectives

Students will:

- Work in teams to gather and graph data, generate a manual fit line, and an equation for their line
- Students will practice making predictions from a linear equation and will test those predictions

Level

Middle Grades: Nature of Science

Common Core State Standards for Science Content

LTF Science lessons will be aligned with the next generation of multi-state science standards that are currently in development. These standards are said to be developed around the anchor document, *A Framework for K–12 Science Education*, which was produced by the National Research Council. Where applicable, the LTF Science lessons are also aligned to the Common Core Standards for Mathematical Content as well as the Common Core Literacy Standards for Science and Technical Subjects.

Code	Standard	Level of Thinking	Depth of Knowledge
(LITERACY) RST.9-10.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.	Apply	II
(MATH) A-CED.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.	Apply	II
(MATH) A-CED.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.	Apply	II

Code	Standard	Level of Thinking	Depth of Knowledge
(MATH) S-ID.6a	Represent data on two quantitative variables on a scatter plot, and describe how the variables are related. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.	Apply	II
(MATH) S-ID.7	Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.	Apply	II
(LITERACY) RST.9-10.9	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.	Apply	II

Connections to AP*

AP Physics: I. Newtonian mechanics B. Newton's laws of motion 2. Dynamics of a single particle (second law) F. Oscillations and gravitation 1. Simple harmonic motion (dynamics and energy relationships)

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Materials and Resources

Each lab group will need the following:

meter stick
Barbie® doll
rubber bands

Assessments

The following types of formative assessments are embedded in this lesson:

- Visual assessment of measuring techniques used within the lesson
- Visual assessment of Barbie® bungee jumping

The following assessments are located on the LTF website:

- 2005 6th Grade Posttest, Free Response Question 1
- 2007 7th Grade Posttest, Free Response Question 1
- 2011 8th Grade Posttest, Free Response Question 1

Teaching Suggestions

The task of this activity is to determine the relationship between the number of rubber bands and the jump height that will result in a safe yet thrilling jump for Barbie®. The doll must be allowed to come as close to the floor as possible without sustaining any "injuries." You can ask students to bring in their own dolls or action figures. Each group works with just one doll.

Students should make at least three trials when dropping their doll from each height and then use the average. Instruct students to test-drop several times to practice taking readings. Students will need to plot their data and develop a mathematical equation to extrapolate and predict how many rubber bands will be required for their next jump. Refer to the Foundation Lesson, "Graphing Skills," for assistance with graphing.

Consider dropping Barbie® from a balcony, stadium bleacher, gym bleacher, or band director's platform. Do not tell the students where the test jump will be made, only its height. You may want to vary the location from period to period.

The athletic department usually has a very long tape measure that will simplify the measuring task. If a long tape measure is not available, use a long string with a small amount of weight tied to the end. Lower the string to the ground until the weight just touches, mark the length on the string, and then use a meter stick to measure the string. In addition, you may use a motion detector and LabPro® to determine the height of the jump.

An extension of this activity would be to give students the heights in feet and inches so they must apply dimensional analysis to successfully convert the given height to meters. Refer students to the Foundation Lesson, "Numbers in Science," for help with dimensional analysis.

Buy plenty of rubber bands. Two-pound boxes from an office supply store work well.

Be aware that after several uses the rubber bands will permanently deform or stretch, and this may affect the accuracy of the prediction. Let students discover and cope with this complication in any reasonable way. Some of them may consider pre-stretching the rubber bands, or replacing the old rubber bands with new ones frequently, or replacing the old rubber bands for the final test jump only.

The stretch of a rubber band is dramatically different from the stretch of a spring. A spring is *elastic*—it obeys Hooke's law, and it stretches and unstretches the same way. Instead, a rubber band shows *hysteresis*—it unstretches very differently than it stretches, and it certainly does not follow Hooke's law (see Figure A). Rubber bands are not elastic.

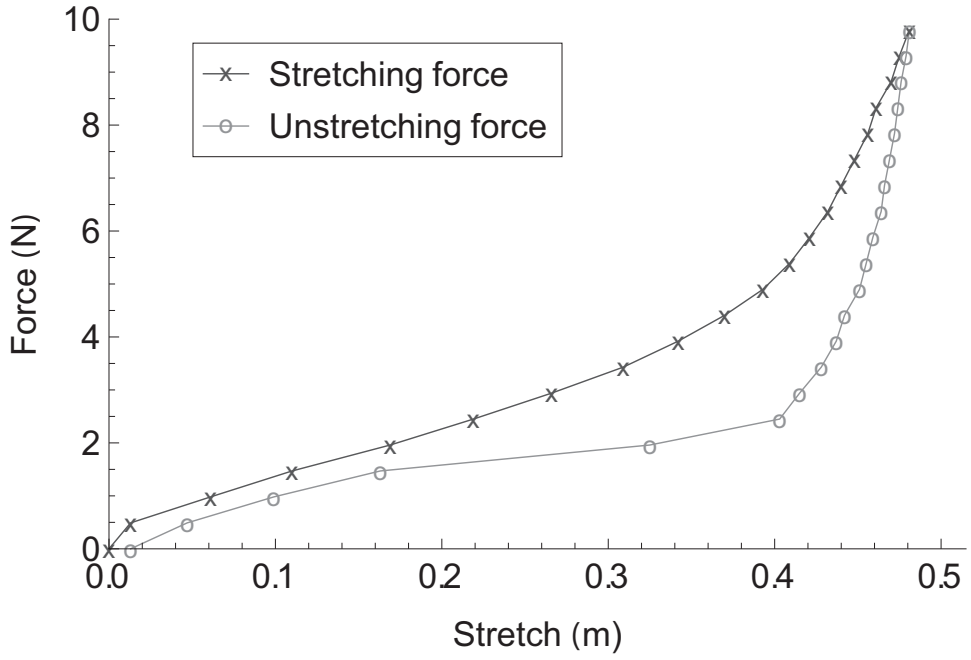


Figure A. Rubber band stretch

For further information about the behavior of rubber bands, there is an extensive lesson in the physics activities named "Hysteresis" that studies this behavior of materials and includes a change in temperature as they change shape.

Although rubber bands are not truly elastic and do not have a definite spring constant, this activity serves a useful purpose in developing data gathering, graphing, inquiry, and data analysis skills.

Acknowledgements

All references to Barbie imply the Barbie® doll or action figure. BARBIE is a registered trademark used with permission from Mattel, Inc. © 2008 Mattel, Inc. All Rights Reserved.

Graphical Analysis®, LabPro®, LabQuest™, and Logger *Pro* 3® used with permission, Vernier Software & Technology.

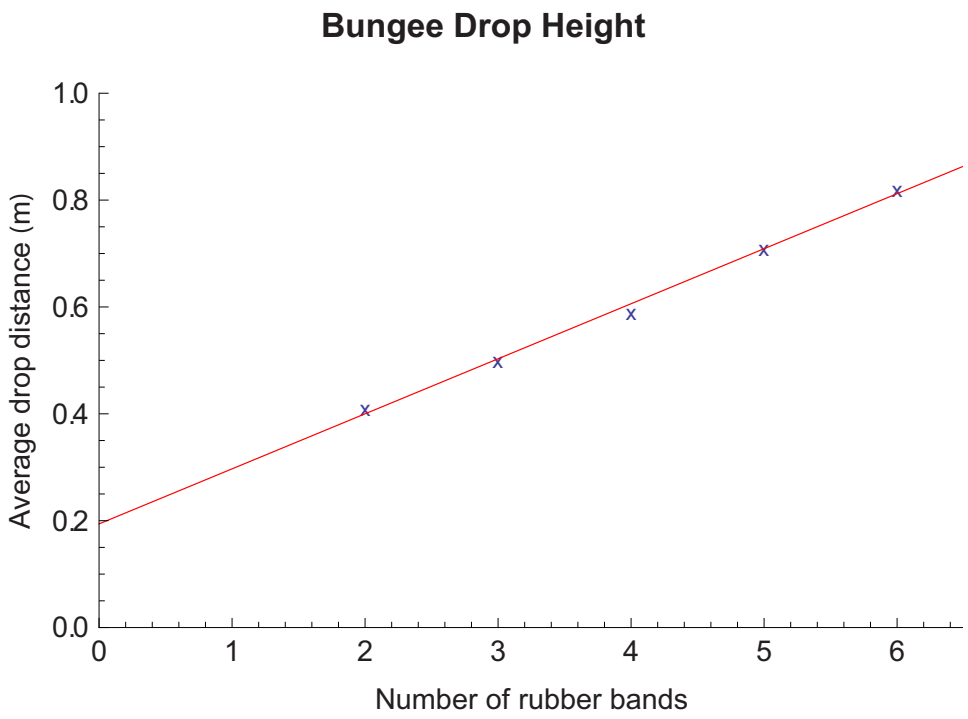
Answer Key

Data and Observations

Data Table

Table A: Bungee Drop Height				
Number of Rubber Bands	Maximum Drop Distance (m)			
	Trial 1	Trial 2	Trial 3	Average
2	0.41	0.40	0.42	0.41
3	0.51	0.50	0.50	0.50
4	0.57	0.60	0.60	0.59
5	0.70	0.71	0.71	0.71
6	0.81	0.82	0.83	0.82

Graph



Answer Key (continued)

Conclusion Questions

1. With a slope of 0.10 and a *y*-intercept of 0.19, the equation of the best fit line is

$$y = 0.10x + 0.19$$

2. A *y*-intercept of 0.19 means that with zero rubber bands attached to the doll, the drop height is 0.19 m. By converting this quantity to inches, this value can yield the approximate height of the doll:

$$19 \text{ cm} \times \frac{1 \text{ in.}}{2.54 \text{ cm}} = 7.5 \text{ in.}$$

3. The slope is the ratio of drop distance to the number of rubber bands included in the bungee cord.

4. First, convert the height to meters:

$$100.0 \text{ ft} \times \frac{12 \text{ in.}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 30.48 \text{ m}$$

   On the graph, the *y*-axis is the height in meters and the *x*-axis is the number of rubber bands used. Thus, the slope has units of *meters per band* (m/band). Because *y* will be equal to 30.48 m, we need to solve for *x*.

   Use a graphing method or do the algebra, substituting the information from your graph into the equation:

$$y \text{ meters} = 0.10 \frac{\text{meters}}{\text{band}} (x \text{ number of bands}) + 0.19 \text{ meters}$$

$$30.48 \text{ m} = 0.10 \frac{\text{m}}{\text{band}} (x \text{ bands}) + 0.19 \text{ m}$$

   Solve for *x*:

$$\frac{30.48 \text{ m} - 0.19 \text{ m}}{0.10 \text{ m/band}} = 302.9, \text{ or about 302 rubber bands}$$

5. Barbie's® boyfriend is a different height and mass, so a bungee cord calculated for her specific height and mass would not be safe for anyone else to use. The cord may be stretched further than is safe, and her boyfriend may suffer serious injury.

6. The number of rubber bands necessary for Barbie® to have a successful and thrilling ride will decrease. The increased mass of Barbie® and her scuba gear means the rubber bands will stretch more, so the slope of the graph will decrease even though the *y*-intercept does not change. This means the number of rubber bands must decrease.

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Team members have been hired to work for the Psycho Entertainment Company. This company provides rock climbing, sky diving, extreme skateboarding, and hang gliding adventures to the public. The current market research indicates that the company should add bungee jumping to its list of entertainment services.

As part of the preliminary research, the management assigned teams the task of working out the details of the jump that will ensure a safe yet thrilling experience. The company has several sites planned for bungee jumping and each site is at a different height.

Purpose

To ensure a safe and thrilling jump, you will determine the relationship between the jump height and the number of rubber bands used to make the bungee cord. You must allow your doll to come as close to the floor as possible without sustaining any "injuries" or "fatalities."

Materials

Each lab group will need the following:

meter stick
Barbie® doll
rubber bands

SAFETY ALERT!

» Use extreme caution during the "jumps."
» Wear safety goggles throughout this activity.

Procedure

1. Use one rubber band to secure the doll's ankles together and to serve as a point of attachment for the bungee cord. Use a small rubber band to tie back the doll's hair if it is not already in a ponytail.
2. Construct a bungee cord composed of 2 rubber bands and attach it to the band on the doll's ankles. The doll should fall freely from a standing position, plunging head-first throughout this activity.
3. Test drop the doll several times to practice taking readings. Repeat this jump two more times, for a total of three trials.
4. Create a data table to record the trials, the number of rubber bands in the bungee cord, and the drop distance. Remember that you will be adding up to a total of 6 rubber bands, and that you will need to record an average maximum drop distance.
5. Add a rubber band to your attached bungee cord. Drop your doll three times using the new cord, and record the data.
6. Repeat Step 5 until you have used a total of 6 rubber bands. Additional trials may be performed if time permits. You may have to devise a way to take measurements that are longer than 1.0 meter.
7. Calculate the averages and record them in your data table.
8. Use the space provided to construct a graph of the average drop distance versus the number of rubber bands. Use a straight edge to draw a line in such a way that an equal number of points lie above and below the line of manual fit.
9. Develop an equation for this line in $y = mx + b$ format and record it on your data sheet. Remember that to calculate the slope of the line, use the equation

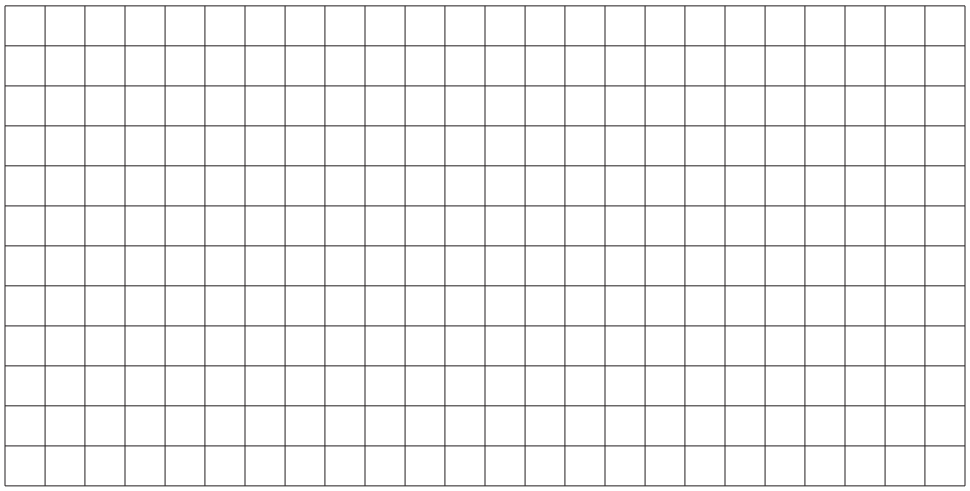
$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

   The *y*-intercept (*b*) can be found by extending this line backward until it crosses the *y*-axis.
10. Use your equation to predict how many rubber bands will be needed for the doll to perform a safe yet thrilling jump from the height of the location that your teacher specifies. Your teacher will set the boundaries for both the doll's safety and her "thrill factor."
11. Create a bungee cord based on the number of rubber bands you predicted in Step 10, and attach it to the doll. When directed by your teacher, proceed to the drop zone and test your prediction.

Data and Observations

Data Table

Graph



Conclusion Questions

1. Write the equation for the line you developed on your graph.

2. What is the significance of the *y*-intercept in your equation?

3. What is the significance of the slope?

4. Use your equation to predict how many of your rubber bands would be needed to allow Barbie® a successful yet thrilling jump from a height of 100.0 feet. Show all calculations in the space provided.

Conclusion Questions (continued)

5. Barbie's® boyfriend wants to bungee jump and have some fun, too. Barbie® loans her bungee cord to her boyfriend but warns that this may not be a safe plan. Why may it be a bad idea for anyone else to use Barbie's® bungee cord?

6. A student determines that 300 rubber bands are necessary to allow Barbie® a successful and thrilling jump from a height of 30 meters. He then decides to accessorize Barbie® by attaching a heavy-duty scuba outfit to the doll. The scuba outfit includes flippers, goggles, and an air tank that combined weigh roughly half of Barbie's® original weight. How will this additional weight affect his prediction of 300 rubber bands? Justify your answer.